CHAPTER 5

FUEL AND SORBENT HANDLING AND STORAGE

5-1. General.

This chapter addresses requirements for fuel handling and storage systems for gas, oil and coal fired boiler plants. Solid fuel policies and procedures are discussed in AR 420-49. Criteria for petroleum product storage and distribution is also prescribed in AR 420-49. While not intended to give the reader a complete in-depth study of handling and storage system design, it is written to give a basic understanding of how to select handling and storage system equipment for a small to medium size boiler plant.

5-2. Gas design considerations.

a. Natural gas is not stored on site. It is furnished through the supplier's pipeline. The takeoff line from the pipe is either furnished by the customer or subsidized by the gas company depending upon how the contract is negotiated. Liquified petroleum gas (LPG) is stored on site in specially built tanks that can either be leased or purchased.

b. Gas piping will be in accordance with ASME B31.8, Gas Transmission and Distribution Piping Systems.

5-3. Oil design considerations.

a. Fuel oil piping systems require special consideration for connections on small pipes. Small threaded fuel oil piping tends to leak due to the penetrating action of oil under pressure. For this reason it is recommended that pipe 2 inches and smaller be socket welded.

b. Fuel oil storage tank design and installation will include spill containment and leak detection. Spill containment can be in the form of a double wall tank or a berm as in the case of above ground installations. Leak detection can be electronic using alarms or it can be visual. An example of a visual system is the leak detection technique of providing underground drainage to a single point next to an above ground storage. A vertical pipe is routed from this point to above ground for periodic visual inspection. A removable cap is used to prevent rain water from entering the pipe.

5-4. Sorbent and alternate fuel considerations.

a. Sorbent or limestone is used for sulfur emissions reduction on atmospheric circulating fluidized bed (ACFB) boilers. Sorbent is transported to the site by truck or rail cars. Sorbent is conveyed pneumatically beginning with site storage if required in a silo and plant storage in a limestone bunker. Pneumatic systems are further discussed in this chapter and also in chapter 6. Bunker design should accommodate all possible sorbents being considered. Cylindrical silos and bunkers are commonly used for sorbent storage. Bunker design considerations for sorbent are similar to coal and are discussed in more detail later in this chapter. It is important to measure the amount of limestone going into the combustor. This is done using a belt scale at the outlet of the bunker. The belt scale discussion later in this chapter is applicable.

b. Alternate fuels such as petroleum coke can be handled similar to coal. Because of the variance of properties within a single fuel type and especially between fuel types, each system will be designed for the fuel being considered and the unique site conditions and operating scenarios.

5-5. Coal handling design considerations.

a. Developing conceptual designs. The process of selecting and laying out coal handling system components should systematically proceed through three preliminary phases before any detailed design work is performed: setting design criteria, evaluating design alternatives, and developing a flow schematic. The design criteria should address such factors as plant location, climatic conditions, available land, system requirements, types of boiler (stoker or pulverized coal) amount of coal storage, conveying rate and method of coal delivery. After these basic criteria have been established, the designer should present a number of different options that will fit them. The feasibility of each option should be examined, and its advantages and disadvantages should be listed and compared to the other alternatives. Because the lowest capital cost system is not always the most economical system, an LCCA will then be made for each of the different design alternatives, taking into account the following considerations: Capital investment costs, operating costs, and maintenance costs. As a final stage of the preliminary design effort, a coal flow schematic as shown in figure 5-1 will be prepared showing each process and piece of equipment the coal is moved through before reaching the plant storage bunkers.

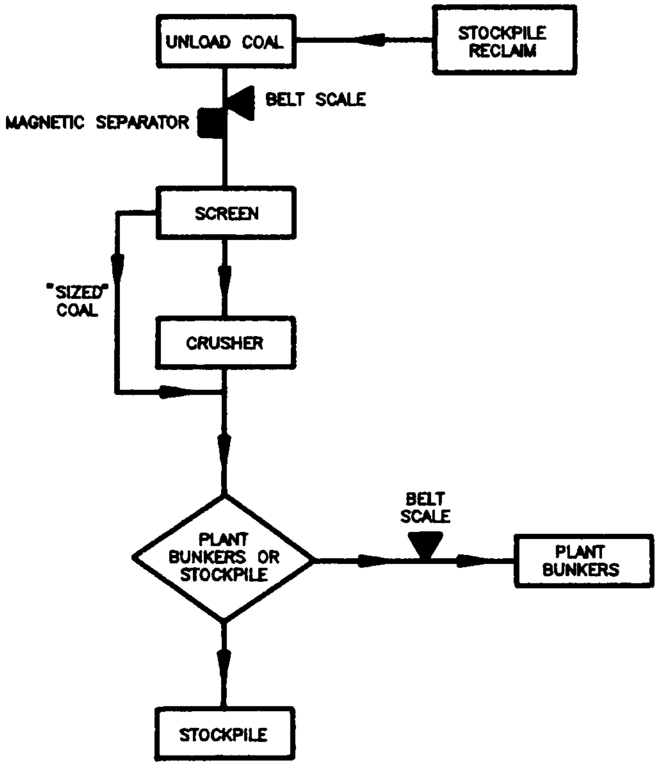

Figure 5–1. Typical Coal Flow Schematic.

b. Climatic conditions. Annual temperature extremes, rainfall, seismic zone and wind conditions will all affect coal handling equipment selection. Hostile equipment environments can dictate what type of conveying system is to be selected.

c. Coal conveying rate. The design conveying rate of the coal handling system depends on the maximum daily coal burn rate of the steam plant, including future increases in coal requirements due to plant expansion. Maximum daily coal requirement is computed by using the maximum continuous ratings of all the boilers and conservative values for boiler efficiency and coal heating values. Once the maximum daily coal burn rate is established, the maximum allowable operating time per day must be defined to arrive at the design conveying rate. It is general industry practice to select the design conveying rate of the coal handling system so it can transport the maximum daily coal requirements to the steam plant in a single eight hour shift allowing seven hours of actual operation time. This criteria allows coal to be handled during the daylight hours and provides adequate time for maintaining the equipment in good operating condition. The amount of running time for an Army Ammunition Plant (AAP) should not be confined to the eight-hour per day limitation. The amount of time that the AAP would be operating at the full mobilization condition has historically been for relatively short periods of time over the life of the plant. One and one-half shifts per day of running time for a coal handling system at full mobilization would be a reasonable criteria to use.

(1) The conveyor should be operating with the belt fully loaded and at minimum speed for the required amount of material to be handled per hour. There is no advantage to be gained by running conveyors at high speed while only partly loaded.

(2) The full load on the belt will be considered as approximately 80 percent of the cross sectional load area of the conveyor belt which must take into account that load carrying width is several inches narrower than the actual belt width.

(3) Maximum belt speed for 24, 30 and 36 inch wide conveyors will not exceed 600 fpm and maximum 800 fpm for 42, 48, 54 and 60 inch wide belts and maximum 1,100 fpm for 72-inch wide belts that carry coal. Wider belts should be limited to 600 fpm if possible. Conveyor belts smaller than 24 inches wide will not be used.

d. Coal characteristics and constituents. Designing for a single homogeneous coal type is generally no longer feasible. Where multiple coals will be burned, the conveyer designer must consider the worst case for his or her design based on coal ranking (according to ASTM standards), particle size and shape (sieve analysis), coal density, moisture content, corrosiveness and abrasiveness, sulphur content, angles of repose and surcharge, safe angle of incline, and coal grindability index. Each factor or combination of factors can dictate the type or size of crusher, transfer chute or conveyor that can safely be used to handle the material. The physical and chemical characteristics of coal make it one of the more difficult bulk solids to handle. Care must be taken by the designer to make sure that he is fully aware of the properties of the coal that is to be handled. A system designed for a western subbituminous coal will not be suitable for an eastern coal, and due to the variable constituents, each different type of coal will have a direct influence on air pollution devices, boiler and equipment design and material handling equipment design.

e. Conveying western coal.. Because of the increasing use of western, low-sulfur coal in recent years, the designer must take into account that equipment sized to handle a given quantity of eastern coal cannot usually handle the same quantity of western coal, even though the conveyor has been sized to handle the lower density and surcharge angles of western coals. This is partly due to the vastly different range of flow characteristics that are inherent in western coal. A rule of thumb for sizing conveyors for western coal is to go one belt size larger than recommended i.e. if a conveyor is sized at 30 inches wide to handle a certain capacity, then use a 36-inch wide belt. Conveyor speeds in excess of 700 fpm are not recommended for western type coal.

5-6. Coal delivery.

a. General. The method of delivering coal to the plant can be a significant cost in the delivered price of the coal and will affect the design, operation and cost of the coal receiving system. The delivery mode depends on such factors as, plant location, distance from mine to plant, daily “burnrate” under full load conditions, available coal storage area and the cost of competitive transportation methods. The ability to receive coal by either truck or rail can be advantageous and create a competitive pricing atmosphere. The ability to accommodate 10-15 railcars or higher multiple car shipments can enable the user to obtain lower shipping rates and reduce demurrage on the railcars due to the amount of time a car spends at the plant. Enough track must be provided at the plant site to allow for the loaded and empty railcars and the unloading area. The economic justification for a loop track or spur track rail storage system can be made as a result of savings in freight rates, if space permits.

b. Truck delivery. Trucks are an extremely convenient form of coal transportation, but due to the high manpower and fuel costs, this type of transportation has become expensive. Over-the-road trucks vary in net carrying capacity from 10 to 40 tons. Trucking coal more than 150 to 200 miles to a plant site usually increases the delivered price of coal to a cost that is financially unacceptable for efficient operation. Truck delivery of coal can usually be incorporated into the design of a railcar unloading hopper. If trucks are the sole method of coal delivery, the designer should investigate the economics of a covered shed over the unloading hopper. Truck hopper should be a minimum of 12 feet by 12 feet with a steel grating covering the dump area. Maximum grating opening should be 6 inches square. Grating should be designed to withstand the loads imposed by the fully loaded truck. Truck weighing scales are optional subject to both economics and justification.

c. Railroad car delivery. This is the most common form of coal delivery to the boiler plant. If a plant has good access to a rail network, the delivery of coal in 70-100 ton railcars is usually more efficient and economical than delivery by trucks. The most common size of railcar is the 100 ton capacity car. The designer should also take into consideration any requirements for the smaller 50 and 80 ton capacity cars which are more popular at smaller sized plants.

5-7. Railcar unloading system components.

a. Railcar scales. Railcar scales are optional for large plants if their use can be justified. These scales are usually not installed in a coal handling system.

b. Railcar haulage. The designer can select from capstan type, drum type, or hydraulic type car pullers. Cost is dependent upon the type of car puller arrangement and accessories provided. The capstan type puller is the cheapest, and is used where one or two cars have to be moved. The capstan puller can only be used on level track, and has very limited capabilities. An alternative for very small systems where three to four cars are moved per week, a front end loader fitted with a railcar moving device should be considered. Drum or reversible type railcar pullers provide more versatility and are becoming the most commonly selected units. The operator makes one connection to a “string” of railcars and pulls them backward or forward, up or down grades, and around curves with a car puller. The designer will ensure that the operator and control panel is well protected from the railcar pulling rope. A railcar string is usually one to twelve fully loaded cars. Hydraulic car pullers are usually the most expensive. They are used at larger plants where high volume railcar moving is required. In making a selection, the designer must take number of loaded railcars, track grade, radius of curvature of track (straight preferred), track condition (new or old), operating temperature, and amount of travel distance required into consideration. The designer should consult a railcar manufacturer for final equipment selection.

c. Railcar shaker. Railcar shakers are used to vibrate the railcar for fast removal of coal from the railcar without the operator having to get inside the car and manually clear the material out, thus reducing unloading time and manpower requirements. Car shakers can be the overhead or side mounted type. Side mounted car shakers require a foundation outside of the rails, and this becomes a problem if there are two or more railroad tracks spaced close together. This type of shaker is more expensive than the overhead type. The overhead shaker is the more common of the two types of shaker, having been in proven use for many years. The designer must ensure that suitable electrical interlocks are provided for the hoist and shaker to prevent incorrect use.

d. Railcar thawing. If the plant is located in a geographical area where the coal would be subject to extreme freezing conditions either from stockpiling the coal, travel time of coal in railcars, or railcars parked on rail sidings for extended periods of time, the designer should make an economic cost comparison to justify whether a railcar thawing system is viable. The car thaw system is used to melt frozen coal from the walls and the bottom of railcars. The thaw system is not intended to completely thaw the entire amount of coal inside the railcar, but rather loosen the bond between the railcar sides and the contents.

(1) *Methods.* There are two very distinct methods used for railcar thawing. The more expensive method is to spray a chemical freeze conditioning agent onto the coal as it is being loaded into the railcar at the mine site. The other method that is employed is electric or gas infrared radiant energy generation. A combination chemical treatment and thawing system is often used, but this is usually very expensive. Direct flame against the side of the rail cars or the use of explosive charges to dislodge coal inside the railcar, will definitely be avoided. A steam thawing system may be required at an AAP due to the explosive atmosphere, where any naked flame or infrared heating device would be prohibited. Steam thawing is not very efficient and can only be effectively used when large amounts of steam are readily available. This type of system should be avoided where possible.

(2) *Design considerations.* The car thaw system should be provided with an enclosure or shed around the thawing area. The shed should be at least long enough to accommodate one heating and one soak zone, when using stationary bottom dump railcars. The shed length should be increased to handle in motion or unit trains. The car thaw heaters are located between the rails and along the walls of the shed. Reflecting side panels may also be utilized to deflect radiant heat into the railcar.

e. Unloading hoppers. The coal hopper must be sized to accommodate the unloading capacity of the delivery system regardless if the coal is delivered by rail or truck. The hopper should have enough capacity to hold at least 100 tons of coal from a stationary positioned railcar, without the coal spilling over the tracks. The actual unloading schedule of the railcars or trucks is very important and should be timed to prevent overloading a limited capacity hopper. If railcars are to be unloaded quickly or on the move, the sequencing of the railcars, the track hopper size, and the size of the track hopper conveyor must all be coordinated together so that a choking condition does not occur.

(1) *Sizing.* A double hopper arrangement, approximately 28 feet long by 14 feet wide will allow a 100 ton capacity railcar to be placed over the unloading hopper without respotting the car.

(2) *Design considerations.* The structure will be designed to support the fully loaded railcar and a fully loaded hopper. Bar grating will be provided to protect against personnel and vehicles falling into the hopper. Grating will support the weight of a truck or front end loader. Grate spacing should be a maximum of 6 inches square. The slope angle of all sides of the hoppers will not be less than 65 degrees from horizontal. The angle of the hopper where two sides meet or valley angle will not be less than 60 degrees from horizontal. Provide capped poke holes at the hopper outlets for use if the hopper becomes plugged.

(3) *Materials.* A number of track hopper construction options exist and these should be evaluated by the designer for each particular application and the type of coal used. The more common construction materials include three types. The first is A588 also known as weathering steel with minimum 3/8-inch plate thickness. This type material should not be used for high sulfur coal. The second type is A-36 mild steel minimum ¾-inch plate thickness, with minimum ¾-inch thick type 304 stainless steel bolted or plug welded liners or studs. This type should not be used for high sulfur coal. The third type is solid stainless steel, minimum %-inch plate thickness. The type of material used for hopper construction will be determined by the type of coal being handled. Solid stainless steel hoppers are not usually installed due to the extremely high cost of the material.

5-8. Belt conveyors.

a. Conveyor design. Belt conveyors are used most extensively in coal handling systems. They have high handling capacities and offer unlimited possible combinations of length, speed, and capacity. Operating costs and power requirements are low and they are reliable and quiet. Belt conveyors can be designed for practically any desired path of travel limited only by the strength of the belt, conveyor incline or decline, or the space available for installation. Troughed belt conveyors normally require more space than other types of conveying equipment. The designer must make sure that all conveyor components are suitable for use in a coal dust atmosphere as described by the NFPA and NEMA.

b. Angle of conveyor incline and belt width.

(1) The angle of repose of a material can indicate to the designer how a material reacts while being conveyed on a running conveyor belt. This angle will affect both the capacity and incline limitations of the conveyor. The inclined angle of a belt conveyor should be limited to 15 degrees, with 18 degrees used as an absolute maximum for coal. High angle conveyors are currently being used by various companies, and the designer should investigate these before a final design is accepted. High angle conveyors use another belt to “sandwich” the material for higher conveying angles. Belt replacement on high angle, flexible sidewall and pocket conveyors is more expensive than conventional belts. High angle type conveyors have more carryback. Conveyor design must consider dirty conditions. Pocket conveyor life is approximately 10 years, while smooth conveyor expected life is 15 years.

(2) The width of the conveyor belt is determined by several factors: the type of material being conveyed, size of lumps, percentage of lumps to fines, the angle of repose of the material and the required belt capacity or conveying rate.

c. Walkways. All conveyors will be provided with a walkway of at least 30 inches in width, including a handrail. Conveyors that are larger than 36 inches wide will also have an additional 18 inch minimum width maintenance walkway on the opposite side.

(1) Walkway construction may be welded bar grating or serrated type expanded metal grating, but wooden walkways will not be used. The designer will provide adequate access walkways for all conveyors and equipment. Provide adequate width stairways to and from platforms and walkways.

(2) The distance from the conveyor belt line to the top of the conveyor walkway should be between 36 and 42 inches.

d. Weather covers. For open truss conveyors, the belts must be protected from rain and freezing and dust must be prevented from escaping to the atmosphere.

(1) Full or three-quarter cover type, hinged weather covers will be used to protect the belts, yet allow maintenance of the conveyor belt and idlers from the walkway.

(2) The truss will be covered with a continuous deck plate. A typical open truss conveyor is shown in figure 5-2.

(3) For more extreme climates where freezing conditions are a hazard or when airborne dust must be totally eliminated, a totally enclosed type gallery as shown in figure 5-3, should be considered. This type of gallery is far more expensive than the open truss conveyor. Enough room must be allowed around each conveyor in the gallery for maintenance. Tube type galleries are more easily built, insulated and lagged, and washed.

e. Safety escapes. Conveyors will include means of egress that comply with all applicable codes. In no case will the distance from any location on the conveyor to a safety escape to grade level exceed 200 feet.

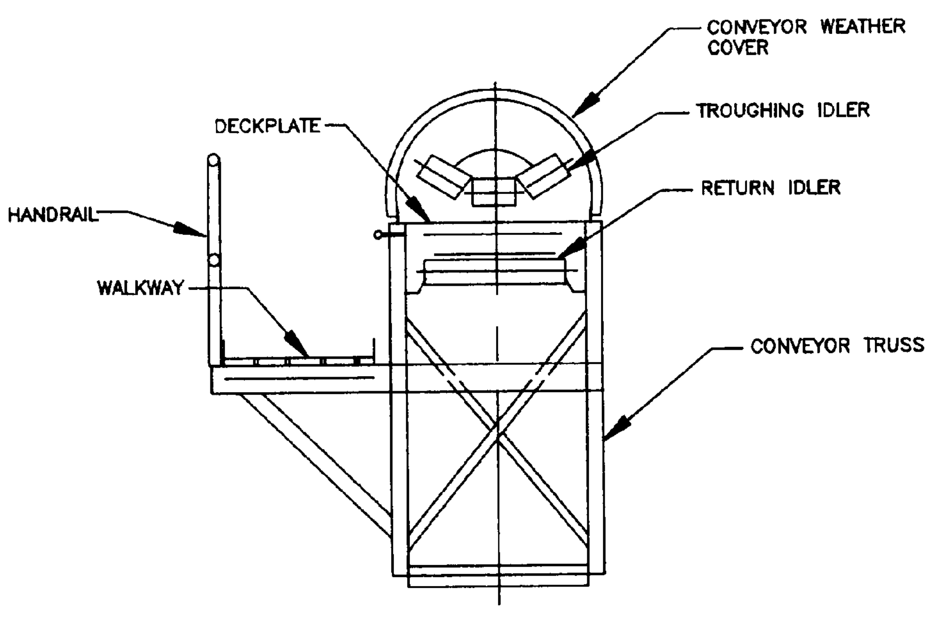

Figure 5-2. Open Truss Type Conveyor.

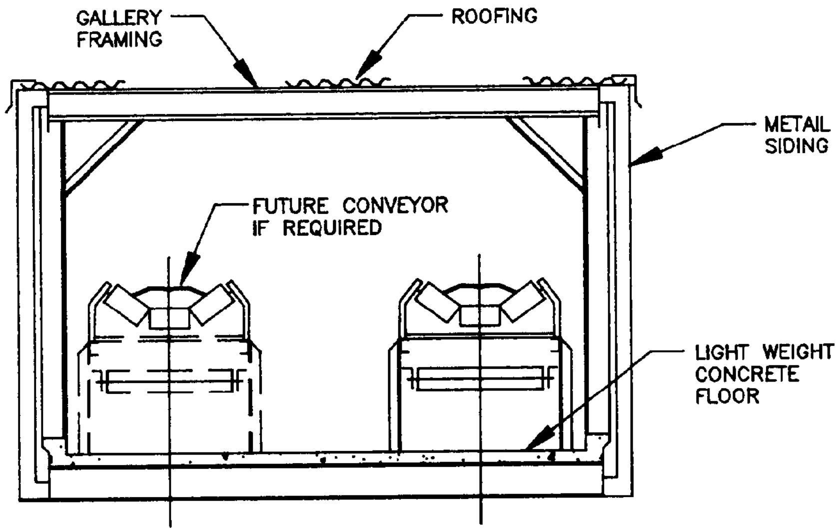

Figure 5–3. Enclosed Gallery Conveyor.

f. Idlers. Idlers will be selected for a specific condition since they provide the support and protection for the belt and material load and also influence the overall design of the conveyor. Improper idler selection directly affects the belt tensions and thus the final horsepower requirements.

(1) Troughing idlers will have a minimum of three 5-inch diameter equal length interchangeable rolls, with the two outside rolls inclined at 35 degrees from the horizontal.

(2) At least 3 rubber type impact idlers, spaced a maximum of one foot apart or urethane bar loading sections will be placed under each conveyor belt loading point. As an alternative, cradles composed of energy absorbing bars may be used under the loading zone to cushion the impact. In installations where more than one cradle is required to cover the length of the loading zone, an impact idler will be placed between the cradles to assure proper belt carriage.

(3) Self aligning carrying and return idlers should be placed at 80-foot centers along the length of the conveyor.

(4) All idlers will have a single point grease lubrication system that is accessible from the walkway side of the conveyor.

(5) Idler construction, selection and spacing will be based upon Conveyor Equipment Manufacturers Association (CEMA) standards.

g. Belt take-ups. Belt take-ups are necessary to maintain the proper belt tensions for the drive pulley traction and to maintain correct amount of belt sage between idlers. Gravity type take-ups should be provided on all conveyors with adjustment of at least three percent of the conveyor terminal centers.

(1) Counterweight will be adjustable *+/-20* percent from the calculated weight. Counterweight will be designed to limit conveyor belt sag to 2 percent and provide adequate traction for the drive pulley. Loading zone belt sag will be maximum 1 percent.

(2) Screw type takeups are satisfactory for conveyors less than 40 feet in length, but should be avoided if at all possible.

h. Conveyor belt selection. One of the most important design considerations is the selection of the conveyor belt. The belt has to withstand both the initial start up and operating tensions that are encountered within the system, be impact resistant and be suitable for the material being conveyed.

(1) The conveyor belt selection must be capable of transmitting the maximum belt tension in the conveyor, include the minimum number of belt plies to support the load, pulley series, take into account the type of material to be conveyed, and minimize belt cost to cover the above items.

(2) Conveyor minimum belt cover thicknesses will be $^{1}/_{16}$-inch thick bottom cover (belt side which contacts the idlers and pulleys) and C-inch thick top cover (belt side in contact with the material).

(3) The conveyor belt selected must be capable of withstanding all startup and operating tensions that will be encountered within the conveyor. For a multiple ply conveyor belt, the unit tension is expressed in pounds per inch belt width (piw) or pounds per ply inch (ppi). A 30-inch wide,

3 ply belt with a maximum calculated operating tension of 5000 pounds, will have a unit tension of:

$\frac{5000}{30}$ = 167 piw or 56 ppi

(4) Conveyor belt sag between carrying idlers should be limited to two percent, except at load zones limited to 1 percent.

(5) Belt tension will not exceed 70 percent of the Rubber Manufacturers Association (RMA) tension ratings under normal operating conditions with a vulcanized splice.

(6) Conveyor belt will be fire and oil resistant conforming to United States Bureau of Mines Standards.

(7) Consideration should be given in applications of limited takeup or long conveyors to provide a mechanical splice when the belt is first installed so initial stretch can be taken out before doing the vulcanized splice. In these cases run-in time will be long enough to eliminate manufacturer's stretch. Vulcanized belt splices generally last close to the life of the belt. Mechanical splices last two to three years.

i. Skirtboards. Skirtboards will be provided at all conveyor loading points. Coal handling system design, especially when handling lignite or western coal requires examination of flow velocity differences between conveyors, vertical drop at transfer points, and angular relationship of conveyors. The width of the skirtboards will be maximum 3/4 belt width.

(1) Skirtboard length will be at least 2 feet for every 100 fpm of belt speed plus 3 feet at tail end. Minimum skirt length will be 8 feet. The skirtboard will terminate above an idler roll, not between.

(2) Skirtboard rubber strips with easy adjustable clamps will be provided on the lower edge of the skirtboards to prevent the escape of fines. Wearable liners inside the chute will be installed as a dam to keep the material load off the rubber, so it can effectively serve as a fines barrier. Provide continuous skirtboards on feeder conveyors.

j. Belt cleaners. Belt cleaner units on a troughed conveyor belt will consist of a primary scraper on the face of the head pulley and one or more secondary arm and blade type multiple blade cleaner to scrape and remove the material that bypasses the primary cleaner. Each belt cleaner will be held in an easily serviceable mounting system allowing fast and easy blade replacement. The cleaners will be held in position against the belt by means of a tensioner which rotates the blades against the belt yet which allows for relief when mechanical splices or other obstructions pass. Do not use counter-weighted type cleaning devices on conveyors faster than 350 fpm or larger than 36-inch as they become ineffective very quickly. V type belt cleaners will be provided on the clean side of the belt before belt take ups and tail pulleys.

5-9. Other conveying methods.

a. Bucket elevators. These are used to elevate coal to overhead storage or conveyors, where there is little available space for a belt conveyor. Malleable iron, steel, stainless steel, aluminum or plastic buckets can be selected depending on the material conveyed. Care should be taken when selecting nonmetallic type buckets for use in a combustible environment, due to their ability to retain a static electrical charge. Capacity of the bucket elevator will be based upon buckets filled to 75 percent theoretical capacity for loading. Drive horsepower will be based upon 100 percent full buckets. There are two common types of elevator used for coal handling: centrifugal and continuous.

(1) *Centrifugal type.* Centrifugal discharge elevators are the most frequently used type for free flowing, fine or small lump materials. Buckets should be type A or AA as designated by CEMA, spaced at intervals to chain or belt. Buckets are loaded by a combination of material flowing into the buckets and material that is scraped up by the digging action as the buckets pass around the tail pulley. Speeds are relatively high and the centrifugal action controls the discharge from the buckets. Capacities range from 5 to 80 tons per hour (tph). Elevator will be completely self supporting. Centrifugal type elevators are used extensively in grain service and other free flowing materials. Centrifugal elevators tend to create more dust and cause breaking of friable material, which creates problems with boiler requiring a particular size distribution. Centrifugal elevators if used should be vented, and include a filter to relieve the "air pumping" phenomena at discharge.

(2) *Continuous type.* Continuous bucket elevators are recommended for high capacity heavy duty service. The buckets are steel, continuously space on single or double strand chain or on a belt. At the head, the discharge from each bucket is over the back of the preceding bucket which forms a chute to lower the material to the fixed discharge spout. This method of discharge, plus the slow speed, minimizes breakage of fragile material. These types of elevator are not the self digging type, so a loading leg must be used, requiring a deeper pit than that needed for a centrifugal discharge elevator. Capacities from 15 to 300 tph are available. Elevator will be completely self

supporting. Bucket elevators are usually high maintenance items and should only be used where space restrictions apply. Manufacturers have to take particular care when designing the track and load shoe.

b. Apron conveyors. Apron and pan conveyors consist of overlapped steel pans which are supported between two strands of chain that pass around head and tail sprockets. This type of conveyor is usually short, slow speed, and used for removing granular or lumpy material from under the track hopper. An apron conveyor is a very high maintenance item and should be avoided when possible. Maximum conveyor incline is usually up to 25 degrees or 45 degrees with pusher plates. One distinct advantage of this type of conveyor is they can carry hot materials.

c. Screw conveyors. Screw conveyors are an economical short, low tonnage type of conveyor which can be used in areas with low headroom. Screw conveyors are not usually used when their capacities exceed 50 tph. They are used to handle pulverized, granular or noncorrosive materials where product agitation or degradation can be tolerated. Where mixing or blending is required, numerous conveyor screw configurations are available. The conveyor is completely enclosed with only one moving part and can be fitted with multiple or single discharge openings. Extreme caution must be taken when handling abrasive materials, as excessive wear will lead to premature equipment failure. As the screw conveyor is inclined, the carrying capacity decreases. Trough loading should not exceed 30 percent of the trough cross sectional area for coal, even though higher loading is possible.

d. Flight conveyors. Flight conveyors are used to move granular, lumpy or pulverized material along both horizontal and inclined paths. Inclines are limited to approximately 40 degrees, with capacity decreasing as incline increases. One percent of capacity should be deducted for each degree of incline over 30 degrees. Flight conveyor is a high wear, very noisy and high maintenance item. With abrasive materials, the trough design should provide for renewal of the bottom plate without disturbing or removing the side plates or flights. A method of compensating for unequal chain wear or stretching must be incorporated into the design. Flight conveyors are well suited to conveying bottom ash from boilers and sludge from tanks and ponds.

5-10. Drive units and couplings.

a. Conveyor drive units. The conveyor drive unit should be located at the discharge or head end of inclined and horizontal conveyors. The designer may find it preferable to locate the drive internally or at the tail end of the conveyor if required by accessibility or maintenance, but should be avoided if possible. The drive arrangement should be designed with the minimum amount of compact components as possible. Reducers, couplings and motors should be the same size as far as practical for ease of maintenance and to reduce spare parts inventories. On conveyor drives over 300 hp the designer should investigate the economical justification of dual drives. This type of drive allows the conveyor to be operated at reduced capacity when one of the drive units fails. V belts will not be used.

b. Reducers. The conveyor drive reducer will be American Gear Manufacturers Association (AGMA) rated using a service factor of 1.5 of the input motor design hp. The thermal hp rating of the reducer will not be less than the full load hp of the motor. Bearings will be Anti Friction Bearing Manufacturers Association (AFBMA) 100,000 hour L-10 minimum life. All conveyor drives will be capable of starting under full loaded conditions. V belts will not be used.

c. Couplings. Power from the reducer drive low speed shaft is transmitted to the conveyor head or drive pulley by the use of a flexible coupling. The coupling will be capable of withstanding parallel, axial and angular misalignment of the drive shafts. The coupling will be incapable of transmitting axial loading and the use of torque limiting couplings will not be permitted. Couplings will be rated using a minimum service factor of 2.0 for the input hp.

d. Fluid couplings. Fluid coupling will be provided between the drive motor and the reducer which allows a controlled amount of slip to occur without causing excessive tension and shock loading to the drive components and conveyor belt. A fluid coupling will allow the motor to run rapidly up to full speed, but will allow the conveyor a smooth controlled acceleration start curve when starting from rest when either empty or fully loaded. This type of coupling is also beneficial in extremely cold climates where a controlled acceleration start is required to prevent coal from backsliding on inclined conveyors. Fluid couplings permit the use of standard motors with across-the-line starting capabilities which allows the use of less expensive motors.

5-11. Belt scales.

a. Scales. General Belt scales are used to constantly measure the rate at which a bulk material is being delivered to the plant on a moving conveyor belt, and to make a record of the delivered amount for inventory purposes. It is important to weigh the coal as it is delivered to the plant, and again before it is burned.

b. Type. A belt scale of the weighbridge type which incorporate electronic precision strain gauge load cell and microprocessor based technology with automatic calibration capabilities should be selected. The belt scale, including weighbridge assembly will be capable of withstanding at least 250 percent material overload without damage to any mechanical or electrical components.

c. Scale accuracy. If a belt scale is to be used for basis-of-payment contracts between the coal supplier and the plant, the coal supplier may require a scale with 0.125 or 0.25 percent repeatability accuracy. For general plant inventory purposes, a 0.5 percent accuracy is usually acceptable. If a scale is used for billing purposes or invoicing freight, approval and certification by the weighing bureau which has jurisdiction for that particular geographical area must be obtained.

d. Readout. The scale can be connected to a computer or a printer to provide a readout of the quantity of material delivered to the plant. The readout will be easily readable by the operator and be such that he does not have to do any manual calculations to find the amount of coal received.

5-12. Sampling system.

a. General. When a given consignment of coal is delivered to the plant, it may be advantageous to the plant to determine by laboratory analysis some of the characteristics of the delivered coal. Sampling is used to take a representative sample from the complete coal consignment lot and provide a quality evaluation of that sample. Because of the variability of the chemical composition of the coal, the analytical results from a sampling system can be used to determine coal contract rates, reliable and efficient quality assurance, plant operating efficiency and compliance with environmental standards.

b. Design conditions. Each sampling system will be designed for a specific location and on an individual plant basis. One sampling system cannot necessarily be used for another similar system. Depending on the capacity of system, one or more sampling stages may be required to obtain the volume of the final sample required for analysis. ASTM standards establish the requirements of the final sample for each particular system. A good rule of thumb for selection is a three stage system is used for flow rates which exceed 2000 tph and when product size is greater than 3 inches, while a two stage system is used where flow rates are below 2000 tph and product size is below 3 inches. Sample system manufacturers will provide help with system sizing and requirements. Due to the complexity and high cost of sampling system, the designer must decide if a sample system is a justifiable piece of equipment to meet the end results.

c. Sweep type sampling. Sweep type (or hammer type) are relatively new and have different design conditions than given above. This type takes less sample than a cross stream type, usually from 1/3 to 1/6 less, depending on conveyor speed, material size and flow rate. This allows two stage sampling systems to be employed with virtually any flow rate using sweep samplers for the first and second stages. Also, for low capacity installations of approximately 50 tph and below, a single sweep sampler with sample collector can be used to meet ASTM D 2234. At these low flow rates, a manageable amount of sample is collected for laboratory analysis with a minimal capital investment.

5-13. Magnetic separators and detectors.

a. Magnetic separators. Magnetic separators are installed to remove potentially damaging magnetic tramp iron from the material on the conveyor belt. Tramp iron is removed from the conveyed material by the separator and can be automatically or manually discharged to a collection hopper. A single unit mounted ahead of the crusher on the conveyor is usually all that is required to protect a complete conveying system. A small piece of tramp iron can put an expensive crusher out of action very easily. The separator will also protect the conveyor belts from being ripped by large pieces of tramp iron. A separator is a relatively inexpensive and necessary method for protecting crushing machinery, conveyors and the plant boilers.

b. Detectors. Detectors are used to detect both magnetic and nonmagnetic tramp iron and are usually installed in conjunction with a magnetic separator to provide additional protection for all downstream equipment. When tramp metal is detected, the unit automatically die marks the location and shuts down the conveyor before any damage is done. The operator has to manually remove the foreign material before restarting the conveyor.

c. Magnetic pulleys. Magnetic pulleys can also be used to remove tramp iron, but are usually not as effective as a magnetic separator, and are seldom used in coal handling systems.

5-14. Coal crushing equipment.

a. General. Stoker fired or pulverized coal boiler plants install crushers for use when a larger and more coarse ROM coal has been purchased for use in the boiler plant. A separate crusher bypass chute should be provided to divert coal around the crusher when properly sized coal is purchased and no crushing is required. The separate bypass chute is also advantageous when maintenance work has to be performed, requiring the shutdown or removal of the crusher from the coal handling system. In boiler plants that have both pulverized coal and stoker fired boilers, all the coal supplied is sized to suit the stokers, with coal going to pulverizers when required. This simplifies the storage and handling facilities required for the system. The crusher will be selected to handle the hardest material that may be encountered in the system. A stationary or vibrating grizzly screen placed ahead of the crusher reduces the crusher size. This can be part of the feed chute to the crusher.

b. Crusher sizing. Generally, crusher drive motor sizing is 1/2 hp per tph for roll crushers, granulators and hammermills and one hp per tph is used for sizing impactors.

c. Coal reduction methods. Reducing coal to smaller size can be separated into the two categories of breaking and crushing. Breakers reduce raw mine coal into a manageable size, while crushers break the coal down to small manageable particles. Rotary breakers are used to crush or size run-of-mine coal by gravity impact and are often used to clean debris from coal which has already been sized. This type of breaker is usually used at the mine site and not at the boiler plant location. When used at a boiler plant, a built in hammer mill is included.

d. Crusher types.

(1) *Roll crushers.* Roll crushers compress the coal between a roll and a breaker plate. Teeth on the roll help to split the coal through impact and toward the bottom of the breaker plate, the teeth shear the coal, which minimizes product fines and reduces power demand. Adjustable clearance between the breaker plate and roll determine the finished product size. The breaker plate is usually spring loaded for protection against uncrushable debris and adjustable from outside the machine. Roll crushers are well suited for western coal due to control on minimum size of product.

(2) *Hammermills.* Hammermills break the coal by the impact of rotating hammers throwing the coal against breaker bars and then dragging the coal against the screen bars. This type of crusher is used as a primary reduction of dry or friable material where uniform product size is required and large amounts of fines are not objectionable. Hammermill crushers must be provided with a vent arrangement because of the air being displaced by the high speed rotating hammers.

(3) *Granulators.* Granulators crush coal with a slow, positive rolling action which produces a granular product with a minimum amount of fines. Power plants particularly choose this type of crusher for its high reduction ratio and high capacity. The product size is externally adjusted by changing the clearance between the case assembly and the ring hammers.

(4) *Impactors.* Impactors break the material by dropping it centrally into the path of the rotating hammers. The material then impacts against breaker plates and rebounds back into the rotating hammers. A variety of product sizes can be attained by adjustment of the breaker plates. Impactors are usually recommended for secondary and tertiary crushing applications where high reduction ratios, high capacity and a well shaped and graded product are required.

5-15. Vibrating feeders.

a. General. Vibrating pan feeders consist of a pan or trough to which is imparted a vibrating motion so that material moves in a controlled flow. Feeders are instantly adjustable for capacity and controllable from any near or remote point. Feeders are normally positioned under track hopper openings, the bottom of a bin or under a storage pile to induce and regulate the flow of material onto a belt conveyor or other means of moving coal. Vibrating feeders are used for handling practically all kinds of bulk materials, but will be avoided where the material has a tendency to stick to the pan. The feed rate in tons per hour of the feeder is a function of bulk density, material size, material angle of repose, angle of decline, frequency of vibration, trough stroke and feeder length.

b. Feeder design. Feeders will be the electro mechanical type which employ easily adjustable, rotating eccentric weights driven by a heavy duty electric motor which transmits power to the feeder pan through heavy duty springs, which in turn induces the material to flow. Electromagnetic type feeders will be avoided where possible. These type of feeders have an extremely high noise level when installed in underground pits and tunnels, and have trouble meeting explosionproof atmosphere requirements.

(1) Each feeder will be designed and sized for nonflushing operation.

(2) Hopper design and inlet arrangement to the vibrating feeder are very important in obtaining the required capacity and preventing overloading and choking of the pan. An adjustable depth

limiting gate will be provided to control the depth of material on the feeder pan.

(3) Maximum recommended feeder angle of slope is 10 degrees down from the horizontal. Larger slopes are possible, but care must be taken to prevent the material from "flushing" (self emptying), when the feeder is shut down.

(4) The more common type of primary feeder supports consist of steel cable or bar hangers supported from the hopper or roof support steel above, with spring type shock absorbers in each hanger. A support frame can be used to support the feeder from below if the feeder cannot be supported from the hopper or overhead support steel. The feeder will be provided with at least two safety slings to prevent the feeder from falling in the event of a primary support failure. Application of suspended feeders will take into account "back out" action of the feeder.

c. Feeder construction. Feeder pan will be constructed from a minimum of 3/8-inch thick, type 304 solid stainless steel plate. Replaceable stainless steel liner plates can be used, but are far more expensive to install. Plastic type liner plates should be investigated when a sticky material is being handled.

d. Controls. There are two common types of control systems which are used to control the vibrating feed rate; Silicon Controlled Rectifier and Variable Auto-Transformer. The control system will be capable of adjusting the feed rate from 0 to 100-percent of the vibrating feeder capacity.

(1) *Silicon Controlled Rectifier (SCR).* This is the more commonly preferred method of vibrating feeder control. The SCR is a solid state, variable voltage, soft start control device that can be used for both local and remote operation where a manual or electronic process control signal input is used. A full voltage start circuit is recommended to protect against full inrush starting current.

(2) *Variable auto transformer.* This is a variable voltage device that is used for local, manual control of the feeder feedrate. The auto transformer requires that a servo device be used for dial adjustment. This type of control is being replaced by the solid state circuitry of the SCR, which is capable of both local and remote control.

5-16. Trippers.

a. General. Tippers are used in conjunction with a horizontal belt conveyor to discharge material from the belt at points along its length. Trippers can be stationary or fixed position, arranged with suitable chutework to discharge material to either side of the conveyor or back onto the conveyor belt.

b. Stationary type. Stationary trippers are used to discharge material at a specific fixed location into a bin or silo, or direct the material back onto the conveyor belt to the next point of discharge.

c. Motor driven. Motor driven movable trippers have the tripper frame mounted on wheels, which engage parallel rails supported on either side of the belt. This type of tripper can remain in a specific location for a short time or locked in position for longer periods. Provide a cable reel or festoon cable system to provide power to controls and motor drives. The designer must provide safety devices at each end of the tripper travel to reverse or stop the tripper car. Dust seals will be provided near the lower end of the discharge chutes to prevent the escape of dust from the covered bins or hoppers. For a clean operation hoppers or bins must be vented to release air displaced by incoming coal. Belt propelled tripper cars will be avoided. Traveling trippers are installed in stream plants where material is discharged into multiple bins, hoppers or silos.

d. Winch type. Winch trippers have positive drives using cable connected to both ends of the conveyor, and looped up through winch. No power is required on the tripper. Winch trippers should be used when conveyor would be exposed to weather. Wind can fold the belt which could cause a self-propelled tripper to come off the tracks. Rain or handling material that absorbs moisture could make the rails slippery, which would not adversely affect a positive drive unit such as a winch tripper.

5-17. Conveyor chutework.

a. Chutework design. Design of conveyor transfer and headchutes depends upon the accurate prediction of the material trajectory path as it discharges over the end of the pulley. The curvature of the material trajectory is dependent on the material depth on the conveyor belt, the belt speed, the angle of the conveyor, pulley size and the force of gravity on the material. All the above factors should be considered during the design stage to prevent the material from choking or plugging the chutework and causing material spillage.

b. Chute slope. For good coal flow all chutework side plates will be as steep as possible but will have a slope no less than 55 degrees off horizontal. For western coal slope will be minimum 60 degrees, preferably 70 degrees. The designer must eliminate offsets, turns or changes in direction of chutework as much as possible.

c. Chute liners. Stainless steel or Ultra High Molecular Weight (UHMW) liner plates will be installed on all surface subject to wear or slide, such as "dribble" from belt scrapers landing on chute back plates. Impact type liners or bars will be installed at material discharge impact points.

d. Construction. Headchutes and transfer chutes will be totally enclosed to reduce spillage and fugitive dust. Rubber dust curtains and seals will be provided around the conveyor belt as it enters and exits the headchute. Conveyor headchutes will have at least 2 inches clearance between the edge of the head pulley and the inside of the chute. For belt widths up to 42-inch and 48-inch through 72-inch clearance will be 3-inch. Headchute construction should have provisions to remove the entire pulley assembly and frame so maintenance can be done in the shop. Chutework will be flanged and bolted design with externally mounted bearings and hinged access doors for ease of maintenance. Provide hinged, access doors on both sides or front (above material impact point) of headchutes.

e. Chute pluggage detectors. A tilt type plugged chute detector will be furnished at each transfer point to protect the conveyor from damage. Pressure or resistance type plug chute switches are not as reliable as the tilt type switches and will not be used.

5-18. Coal reclaim.

a. General. Reclaim systems can be classified into two categories, below grade and above grade coal reclaim systems. Small size steam plants usually cannot economically justify the types of reclaim systems employed by the larger power plants such as the above grade reclaimers, bucket wheels, boom mounted bucket wheels, barrel and bridge reclaimers, and the below grade system such as V-shaped slot bunkers, glory holes and underground reclaim tunnels with vibratory or rotary plow devices. These type of reclaim devices require a very large capital outlay. Smaller plants usually employ a combination of both the above and below grade systems.

b. Reclaim hopper. This is the cheapest and simplest form of reclaiming coal from long term storage. In this method an above ground bulldozer moves coal from the storage pile to a below grade reclaim hopper. The hopper will be approximately 12 foot square and covered with a steel grizzly or grillage with maximum 6-inch square openings. The hopper and grillage will be designed for a fully loaded hopper and the weight of a bulldozer, front-end loader or truck. A vibrating apron or belt feeder under the hopper outlet and a manually adjustable strike off gate on the hopper regulate the amount of coal loaded onto the reclaim conveyor. This method of coal reclaim is solely dependent on the front-end loader or bulldozer to move coal to the hopper. There is no “live” reclaim ability with this method.

c. Drawdown hopper. A more expensive method of reclaiming coal is with the use of a vibrating drawdown hopper or pile discharger. The drawdown hopper is located directly under the coal storage pile and is designed to operate on a timed cycle basis, which transmits controlled vibration energy into the coal pile, generating fracture lines, causing the control column of flow to be drawn down into the hopper and onto the conveyor belt. This method of coal reclaim can provide the plant with a certain amount of “live” reclaim from the coal pile minimizing the use of mobile coal moving machinery.

5-19. Wet and dry dust control.

a. General. Whenever a dry material such as coal is moved or changes its direction during a process, the result is fugitive airborne dust. Fugitive dust emissions can be significantly reduced by the addition of an effective dry dust collection system, wet suppression system or combination of both. With the evolution of more stringent air pollution control regulations, coal handling systems are being required to meet these standards for the geographical area they are located in. Federal, State or local clean air codes can rule out the use of one or the other types of dust control systems.

b. Wet dust suppression system. Wet dust suppression system is usually used where the dust producing area is complex, large and unconfined, such as stockpiles or track hoppers.

(1) This type of system uses a proprietary water soluble, surface active, proportioned chemical additive, to dampen and agglomerate fugitive dust particles at the source making them too heavy to be airborne.

(2) The effectiveness of wet suppression systems can range from total suppression in warm weather to questionable operation in cold subfreezing temperatures. Additional moisture can cause coal to stick together complicating the flow characteristics of the material being conveyed, and can reduce the burning characteristics of the coal and are only as effective as the amount of dust that is contacted by the suppressing agent.

(3) A wet suppression system is a simple solution to dust control, that does not require the use of costly or elaborate enclosures or hoods, are cheaper to install and require far less space than a dry dust collection system. Changes or alterations required after startup can be made with the minimum of expense and system downtime.

(4) Foam suppression is simple and efficient. Foaming chemicals have to be purchased. It is ideal where low moisture is necessary. Foam type systems typically add less than ½ percent moisture as compared to up to 4 percent with standard water spray systems. One foam unit is needed for each central application location. No electricity is required. Water and compressed air are required.

c. Dry dust collection systems. Dry dust collection systems utilize dry type bag filters which are designed to remove dust-laden air from unloading areas and transfer points throughout the coal handling system, as well as to provide ventilation for bins, storage silos or bunkers. The main advantage of this type of system is that it can be operated in both warm and cold climates.

(1) A dry dust collection system requires a large amount of space for equipment and ductwork, which makes it more expensive to install than a wet type dust suppression system. Operating and maintenance costs are compounded as the size of the system increases. Changes or alterations required after startup are virtually impossible without completely modifying the entire system. Filter bag replacement for the dust collector units is very time consuming and costly.

(2) The collected dust from the dust collector must be returned to the material flow which allows reentrainment of the dust at the next pick-up point location.

(3) Table 5-1 shows a comparison of dry dust collection versus wet dust suppression systems.

5-20. Conveyor safety and safety devices.

a. General. Conveying system safety begins with good design which, as far as is practical, tries to protect the operator from dangerous or hazardous areas associated with conveyors. Safety should be considered in all phases of conveyor design, manufacture, installation, operation and maintenance procedures. Conveyor operators must be properly trained and made aware of possible recognizable equipment hazards, safety procedures and devices, before they become involved in an accident. Conveyor safety is covered in ANSI B20.1. In addition, the following safety devices will be included for all conveyors:

Table 5-1. Comparison of Dry Dust Collection Versus Wet Dust Suppression Systems.

	Dry dust collection	*Wet dust suppression*	*Foam suppression*
When recommended			
	Enclosed hoppers, bins, silos, transfer/crusher houses. Silo, bunker or bin venting Enclosed track hopper buildings	Open coal storage piles Open or enclosed track hopper buildings. Op en or enclosed conveyor. Transfer points	Stock piles Crushers
Enclosed transfer points			
Note: Where an item is listed under both dry dust collection and wet suppression, an LCCA should be conducted to determine which system should be used.			
Disadvantages			
	More expensive. High operating and maintenance costs. Changes or alteration to system are costly. Time consuming filter bag replacement. Large amount of space required. Collected dust must be returned to the material flow.	Chemical additive be purchased. Questionable cold-weather operation. Moisture is added to coal. Requires a water supply. Requires freeze protection supply.	Foaming chemicals must be purchased
Advantages			
	Can be operated in warm and cold climates. Does not add moisture to coal. Can be used for bin or silo venting,	Less expensive. Does not require costly or elaborate enclosures. Small space required for installation. Changes to system easily made.	Same advantages as wet dust suppression.

b. Safety devices. Each conveyor in a conveying system will incorporate electrical safety devices to provide protection to the operating personnel as well as to prevent damage to the conveyors' mechanical components.

(1) All electrical safety devices will be electrically interlocked so that when a "trip" signal is received from the device at the point of failure, all the downstream conveyors and feed devices, such as crushers and feeders, back to the initial conveyor feed source will shut down immediately.

(2) No conveyor can be started until the safety device has been checked and put back into proper service. Only then can the complete conveying system be put back into operation.

c. Emergency stop switches. Pull cord switches and pull cords will be located along all walkways or areas that are accessible to conveyors to protect personnel from falling into any rotating or moving machinery. Once "tripped" these switches have to be manually reset before the conveyor can be restarted.

d. Belt overtravel switches. Belt misalignment switches will be provided on both sides of the belt at the head and tail end of each conveyor and the tripper, to detect conveyor belt misalignment, which can result in serious damage to expensive belts, drive equipment and structures. Extra switches will be installed at selected intervals, no more than 500 feet apart on long conveyors.

e. Conveyor zero speed switch. A zero speed switch will be provided for each conveyor in the system. They are installed on a nondrive pulley, preferably the tail pulley to detect a decrease in conveyor belt speed, from a given set value.

f. Plug chute switches. A plug chute switch will be installed at each conveyor transfer point. They operate when a plugged chute condition occurs, and are arranged to stop the downstream equipment from continuing to feed the plugged chute. Similar type switches are used in hoppers, bins, silos and chute discharge points. Tilt type switches are the most common type used.

g. Warning horns. Horns are used prior to the conveyor start sequence to warn operating or maintenance personnel that the equipment is being placed into operation. Horns will be operated for at least 15 seconds, before starting any conveyor. Provide enough horns to cover all conveyor areas in the plant.

h. Guards. Rotating or moving machinery which provides a safety hazard to the operator will be provided with a guard or guards to warn the operator that a particular hazard does exist. ANSI B20. 1 gives the conveyor designer guidance on conveyor safety guards.

i. Conveyor backstops. A backstop is a mechanical device which allows a conveyor or bucket elevator drive shaft to rotate in one direction only. An automatic backstop will be installed on all conveyors or bucket elevators subject to reversal under loaded conditions. Backstop will be sized according to conveyor drive motor stall torque, and be provided with a removable torque arm. The backstop will be installed on the conveyor drive pulley shaft and not in the drive reducer.

j. Methane detectors. Install methane detectors and vent system anywhere that coal is stored in an enclosure.

5-21. Spontaneous combustion of coal.

a. General. A major problem with the bulk storage of coal is its ability to release enough heat, through slow oxidation, to raise its temperature gradually until self-ignition or spontaneous combustion occurs. The tendency of stockpiled or stored coal to self ignite increases as the coal ranking decreases.

b. Coal ranking. Lower rank coals tend to be very fragile, resulting in faster degradation and particle size reduction during the handling process. Anthracite type coals, which are the highest ranking coals have few problems and are very easy to handle. Lignite and subbituminous type coals tend to degrade quickly leading to spontaneous combustion.

(1) When these types of coal are stored, provisions must be made to monitor the conditions in the silo, bunker or stockpile to reduce the occurrence of spontaneous combustion.

(2) Precautions must be taken so that material in a silo, bunker or stockpile can be evacuated in the event of material self ignition. Without oxygen, the oxidation process cannot take place, so it is important that the total coal surface exposure to air be as low as possible. Coal should be stored so that air cannot infiltrate or move through the storage pile. Spontaneous combustion usually only results from careless storage procedures. Where coal is properly stored, this likelihood is remote.

5-22. Coal bunkers.

a. General. In the design of bunkers, careful consideration will be given to the capacity, shape, bunker material, and bunker location within the steam plant.

b. Storage capacity. Bunker will be sized for a minimum of 30 hours supply for maximum boiler capacity.

c. Shape. The shape of the bunkers are usually a compromise between space restrictions and optimum design for coal flow. The more common bunker designs are the square upside down pyramid and silo types. Cantenary, straight, or parabolic type bunkers will not be used because the flow of coal from all outlets is not uniform which creates dead pockets and causes a spontaneous combustion hazard. Cylindrical or silo type bunkers are used to reduce danger of spontaneous ignition of coals. To reduce stagnation and coal segregation, separate bunkers will be provided for each boiler. At least the bottom of each bunker should be in the building to preclude bottom freezing. Discharge hoppers will be sloped at least 55 degrees. An emergency discharge chute will be provided for each bunker to remove coal from the bunker in emergency situations. Silo design type bunkers are more frequently used because they have been found to be less susceptible to rat holing and hangups than other shapes.

d. Material. The designer will carefully analyze the type of material being used for the bunker, to insure the material is compatible with the type of coal being stored.

e. Location. Coal bunkers should be located to provide a coal flow which is as vertical as possible. Current trend is to replace plant storage bunkers with inside silos which require less building volume and structural support steel. On the average, it has been determined that the silo and related support steel structure were less expensive than a bunker of the same capacity. The cylindrical shape of a silo has an inherent strength advantage. A properly designed bunker generally can match a silo's flow efficiency, therefore such factors as moisture content, temperature and storage time have the greatest influence on the type of silo or bunker that is selected.

5-23. Long term coal storage.

a. General. The long term coal storage pile is created for the sole purpose of having an adequate supply of coal on hand to supply coal to the boilers in the event of an interruption of coal supplies to the plant.

(1) The reserve or long term coal storage pile should be maintained at the boiler plant. Refer to TM 5-848-3 for the criteria for determining the quantity of coal to be stored.

(2) The method of storing and reclaiming coal in an outside storage pile should be determined to satisfy regulatory environmental restraints. Drainage and collection of rainwater runoff, treatment, coal water separation and neutralizing effluent will be included in design. Local, State and Federal environmental regulations will determine limits for suspended solids and pH of coal pile runoff water and leachate. Treatment facilities will be provided if required.

(3) Care must be taken in the method of constructing the coal pile. Coal is placed in maximum 18-inch thick layers and then compacted with the use of a front-end loader or rubber tired dozer to eliminate air spaces within the pile.

(4) The designer will take into account the "weathering" process or loss of coal heating value, that takes place with long term storage of coal.

(5) Coal handling personnel will be assigned to check a long term storage pile on a daily basis, to guard against localized hot spots caused by spontaneous combustion.

(6) A liner may be required underneath the coal pile to prevent coal pile runoff from being absorbed by surrounding subsoil. Soil permeability tests will be taken in the area where the coal pile is to be located.

b. Environmental regulations. Local and State Regulation Agencies may have environmental regulations which prohibit open storage of coal, because of fugitive dust emissions and runoff. In this case the designer should investigate the use of outside coal storage silos or covered barn structures. Both silos and barns are high capital expense items. Some agencies will allow open storage of coals with wet suppression.

5-24. Fire protection and prevention.

a. General. Fire protection and prevention for a conveying system and its related structures, requires that the designer ensure careful planning during the initial design stage to reduce coal dust. Fire protection systems are playing a more important role in the design of conveying systems. New code standards developed by the NFPA and industry requirements are forcing designers to reexamine coal handling system design and the suitability of the fire protection system. A fire protection system can make a difference between minor damage and total destruction.

(1) Western subbituminous type coals are less dense, more susceptible to spontaneous combustion than the eastern coals. The amount of fire protection required for any system largely depends on the type of coal to be burned at the facility. Some coals can be stored in bunkers for years without any spontaneous combustion generated fires, while other coals such as some types of western subbituminous C type coals cannot be left in a bunker for a period over 30 days. An emergency bunker unloading system will be included in the design to enable the bunkers to be emptied. Western coals tend to produce a higher

percentage of fines during the handling, conveying and stockpiling process, thus causing particles to become airborne, creating a more dusty environment. Coal dust can impair the operation of coal conveying equipment and create an unhealthy working environment which increases the risk of fires and explosions. Methane detectors and a vent system should be installed in coal storage enclosures to reduce danger of explosion.

(2) Conveyor fires are usually started by friction between seized idlers and the conveyor belt, seized bearings or improperly aligned or maintained equipment. If a fire on a conveyor should occur, the conveyor, the upstream and downstream conveyors, auxiliary feed equipment such as crushers and dust collectors must all be stopped immediately.

b. Design. The following items will be given consideration when designing a conveyor fire protection system:

(1) An automatic wet or dry pipe sprinkler system should be installed along conveyors, to protect the carrying and return belts, conveyor drives, underground tunnels and control areas.

(2) Automatic deluge systems require large flow rates to protect the conveyor and the conveyor galleries. The water supply system will be investigated to see if it can support the required flow rates when a fire protection system is determined to be necessary.

(3) Adequate means of removing fire protection water from below grade tunnels must be provided to ensure that personnel can be evacuated before a hazardous water build up occurs.

(4) A dry pipe or preaction type system, which employ a fusible link or glass bulb sprinkler heads, are usually used in areas that are subject to freezing conditions. This type of system is the more popular type of fire protection system.

(5) A wet pipe system, which is basically the same as dry pipe, except that water is in the system piping at all times, is usually suitable for areas not subject to freezing.

(6) A fire detection and evacuation alarm system will be provided throughout all facilities with pull stations at all exterior exits and sufficient evacuation alarms to overcome the normally higher level of noise found in power plants. The fire detection and evacuation alarms will give indication in main and auxiliary control roams and into the plant main fire alarm system.

(7) Adequate fire hydrant protection will be provided for all coal piles and consideration will be given to the long term methods of coal pile storage to minimize spontaneous combustion.

(8) Draft barriers or fire walls will be provided at each end of conveyor galleries.

(9) Safety escapes. Conveyors will include means of egress that comply with all applicable codes. In no case will the distance from any location on the conveyor to a safety escape to grade level exceed 200 feet.

(10) Carbon dioxide, or steam protection should be considered for bunkers, bins and silos. A method of transporting coal from a silo to a remote yard area in the event of a fire will be considered in the design.

(11) There are numerous types of fire detection sensors and detectors such as heat, continuous thermal sensor, fixed temperature spot sensor, fusible thermal wire, pneumatic rate of rise, series thermal detector, smoke detectors, ionization detectors, flame, ultraviolet, infrared and numerous others. There is no single, all purpose sensor or detector for a fire protection system and a well designed system usually requires a wide range of sensors for maximum system protection. Matching the specific type and configuration of the detector or sensor to a particular hazard is very difficult and a professional fire protection systems engineer who has experience with the design and operation of coal handling fire protection systems should be consulted.

5-25. Control system.

a. General. Control of the individual conveying system operations should be conducted from a single control room. The following items should be considered:

(1) The control system will be capable of providing a local manual, remote manual or fully automatic control of the conveying system.

(2) Conveyor controls will be interlocked to prevent coal spills in the event of a system malfunction and to shut the conveying systems down in a set sequence. The controls will provide a foolproof sequential method of starting and stopping upstream and downstream equipment in the conveying system.

(3) A locked remote control panel will be located next to each piece of equipment they control, so that the equipment can be locally operated by maintenance personnel. Local panels will be interlocked with main control panel so that both panels cannot be operated at the same time.

(4) Each system will be adequately monitored with alarm and control devices so that the operating status of the system can be determined from indicating lights on the control room graphic or mimic display panel.

(5) Indicating lights will be provided on a separate annunciator panel for belt misalignment, plugged chute, drive motor overload, emergency stop, zero speed, or any other safety device. The

lights tell the operator at the control panel which piece of equipment has tripped and also the reason.

(6) Motor operated gates and valves will be provided in locations requiring frequent operation, and properly interlocked for starting and stopping in the proper sequence.

b. Computerized control systems. A computerized control system such as a programmable controller (PC) is the most cost effective where logic functions must be accomplished. Advances in micro technology make the cost of computer type controls more economical than the relay based control systems. Field changes to the logic in a PC system can be made without wiring changes. Most units allow a program simulation mode, whereby the PC will diagnose the program and check the logic that has been entered. The computerized system is the preferred method of control.

5-26. En masse conveying system.

a. General. This type of system uses a conveying chain which utilizes the skeletal flight as opposed to a paddle flight, which can greatly reduce the horsepower requirements for the conveyor. The conveyor chain runs in a completely enclosed and sealed trough. The effective conveying capacity can reach as high as 90 percent of the cross sectional area. These conveyors have the ability to convey horizontally, inclined or vertically, which makes them extremely versatile.

(1) En masse type conveyors require approximately twice as much horsepower as a regular belt conveyor to move the same amount of material the same distance. They are also very susceptible to foreign material, which is not the case with belt conveyors. Special care has to be taken when handling abrasive or corrosive materials.

(2) En masse conveyors are advantageous for overbunker distribution systems, offering totally enclosed, multiple or individual discharges which do not require complicated or extensive chutework at the discharge points.

b. Chain. Use short pitch, drop forged alloy steel, carburized or case hardened to 500-600 Brinell Hardness Number (BHN). Each link should be easily removable without cutting any part.

c. Trough. Provide symmetrical panels for wear and maintenance. Sides and bottom plates will be abrasion resistant and bolted for easy replacement.

d. Return rails. Hardness of rails will match the hardness of the conveying chain.

e. Drive sprockets. Provide a segmental type with reversible teeth sections, so that the complete drive shaft assembly does not have to be removed for maintenance. Teeth hardness will match chain hardness.

5-27. Pneumatic conveying systems.

a. General. Pneumatic conveying involves the movement of powdered, granular or other free flowing bulk materials along the pipeline with the aid of compressed air. Pneumatic conveying can be very basically categorized into two areas—dense phase and dilute phase. Suitable materials that can become fluid-like or fluidized are usually only suitable for pneumatic conveying. The product size can also restrict the use of this type of conveying medium. This type of system is sometimes used for moving small tonnages, up to about 50 tph.

(1) Materials that have a high moisture content, such as wet coal are difficult if not impossible to handle in a pneumatic type system.

(2) Pneumatic conveying systems are extremely inefficient when comparing tonnage moved to hp required to move the material with energy consumption as much as five times that of a belt conveyor.

(3) Exotic auxiliary equipment and very costly control components have to be compared with the minimal roam requirements and ease of installation for this type of system.

b. Advantages and disadvantages.

(1) Advantages of pneumatic conveying systems are that they require little maintenance, take up less space than belt conveying equipment, are usually automatic (eliminating manual operations) and are totally enclosed, thus avoiding environmental fugitive emission problems, spillage and dust.

(2) Disadvantages of pneumatic systems are that they usually have a higher operating cost than belt conveying systems because compressed air is used to convey the material and there is a limitation on the maximum size material and the amount of fines that can be conveyed. Coal fines in excess of 40 percent will cause pluggage problems in the conveying pipe. Pneumatic conveying tends to create additional coal fines.